MARS SCIENCE LABORATORY

JPL

Initiating the 2002 Mars Science Laboratory (MSL) Focused Technology Program

February 4, 2004

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MSL Focused Technology Status Review

- Introduction
- MSL Technology overview
- 2002 Technology Implementation
  - Technology Definition
  - Technology Selection
  - Technology Management
- Technology Tools
  - Aggregate Project Plan
  - Technology Funnel Chart
  - Decision Analysis Tools
- Conclusion

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Next Generation Capabilities for EDL

EDL

- Guided Entry
- Hazard Detection and Avoidance
- Modified Viking Engine for Descent
- Robust Landing System

Key Features

- **Precision Guided Entry**
  - Hypersonic Aeromaneuver Guidance
  - Small Landing Error Ellipse (<10km)
- **Autonomous Terminal Descent HDA**
  - Position/Velocity Measurements Using Phased Array Terrain Radar
  - Autonomous Crater Detection and Avoidance
  - Subsonic Chute for Longer Hang Time Needed for Hazard Detection
- **Efficient Touchdown System**
  - Safe Landing of Large Mass using "Skycrane"

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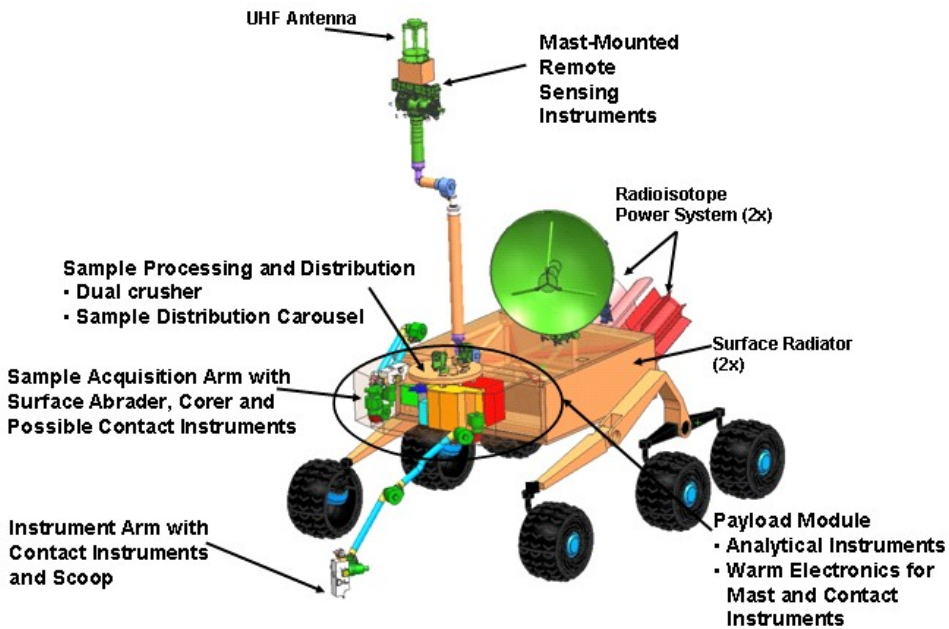
Next Generation Capabilities for Surface Mission

Key Features

- **Robust Software Architecture**
  - Unified Framework for Flight/Ground Software
  - Reusable Components
  - Infusion of Validated Navigation/Placement/Manipulation Technologies
  - Early Demonstration of Fully-Integrated Software
- **Long-lived Mobility Asset**
  - Electronics and Actuators Designed for 1500 Thermal Cycles
  - Recycling of RTG Waste Heat to Control Electronics Base Temperature using Pumped Fluid Thermal System
  - Potential Technologies to Improve Mission Ops Efficiency
- **Sample Acquisition & Distribution**
  - Two Functional Redundant Arms
  - Rock Crusher and Distribution Mechanisms

Surface Systems

- **Flight Software Architecture**
- **Navigation & Instrument Placement**
- **Long Life Elect/Mech Systems**
- **Sample Processing & Distribution**



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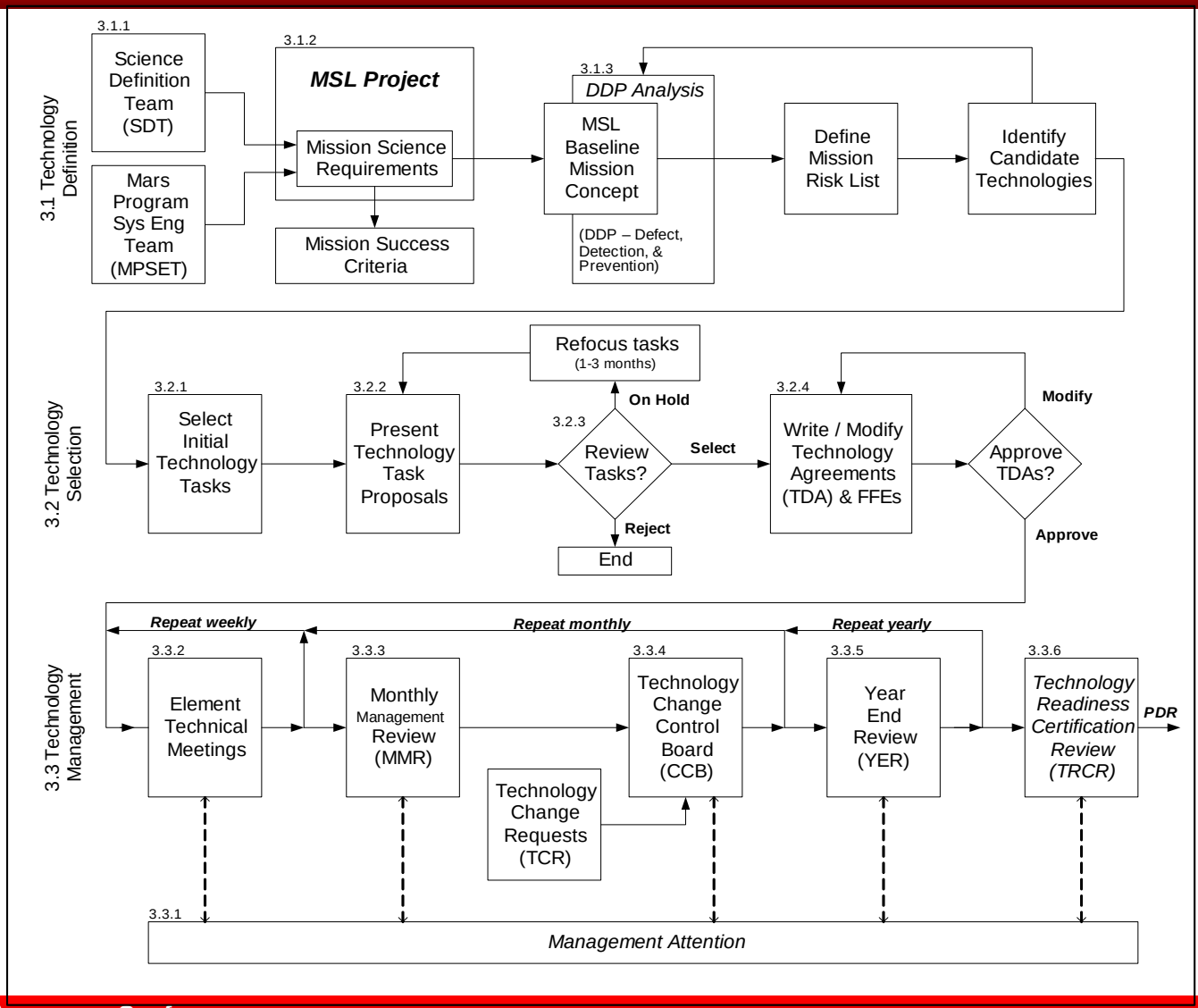
Technology Program Implementation Flow



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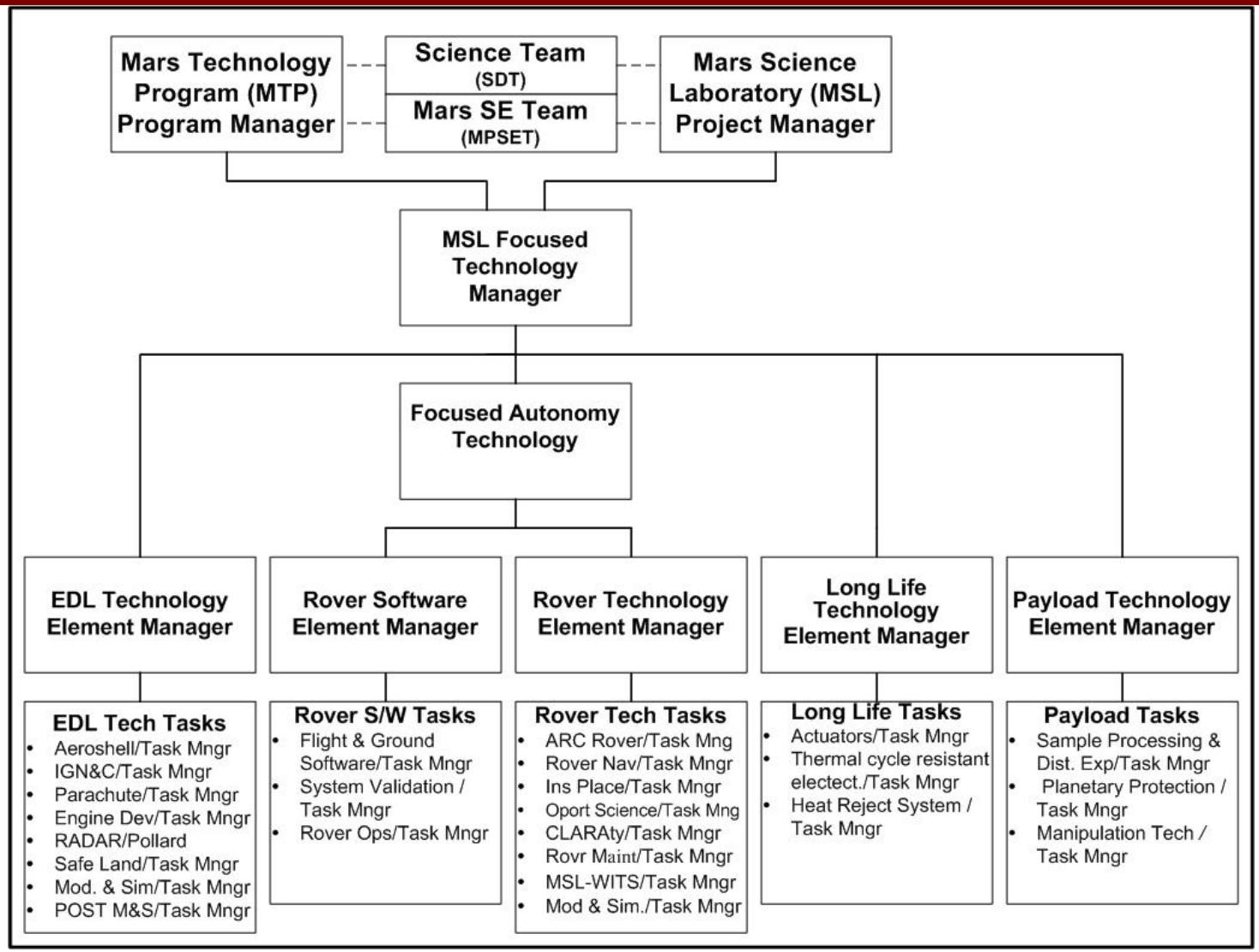
MSL Focused Technology Org Chart



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Mars Program SE Team (MPSET) Charter

- Composed of senior system engineers chartered by and reporting to the Mars Program Manager. …takes on studies, provide advice, and serve as a review body with the explicit objective of ensuring that the Program is optimized as a whole and not on a basis of project by project.
- The Team will identify and prioritize critical trade issues with multi-project implications. It will penetrate the issues to a level needed to draft work statements for targeted study teams who will perform these studies/sensitivity analysis. MPSET will review the output of these studies and make recommendation to the Program for a course of action that balances cost, schedule, risk and capability."

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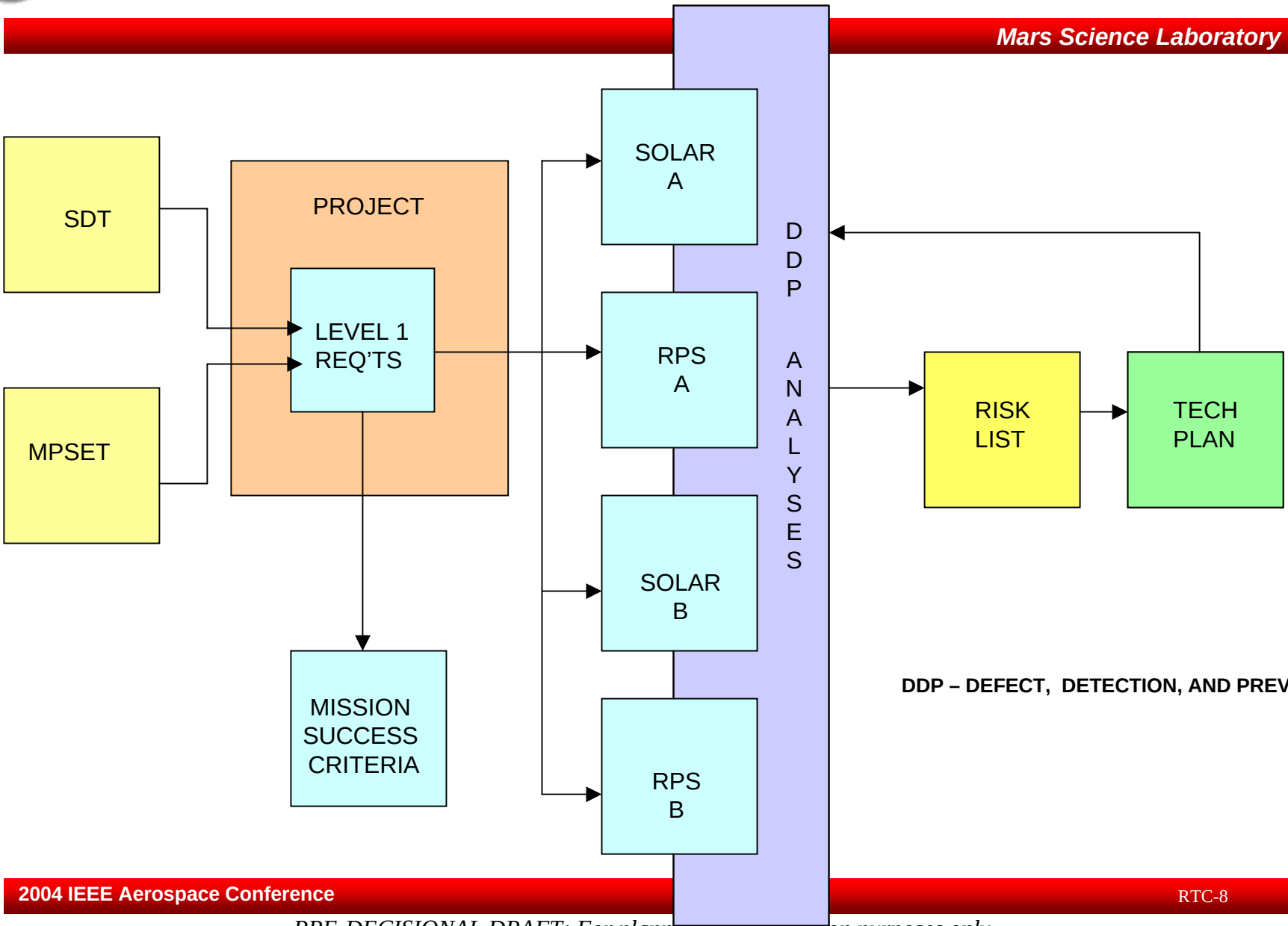
Risk Assessment and Technology Planning



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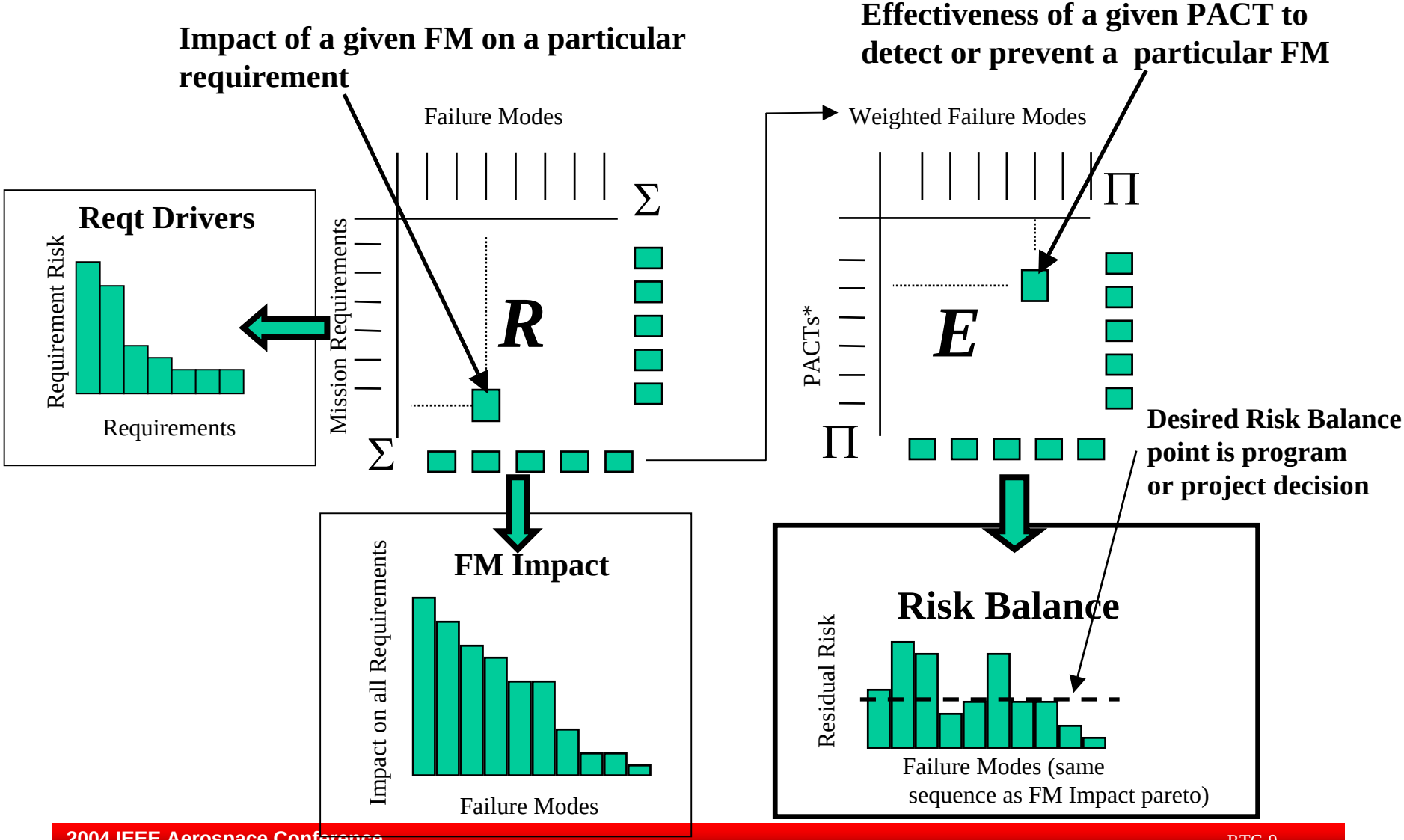
Simplified DDP Summary

DDP utilizes two matrices: the Requirements matrix (*R*) and the Effectiveness matrix (*E*)



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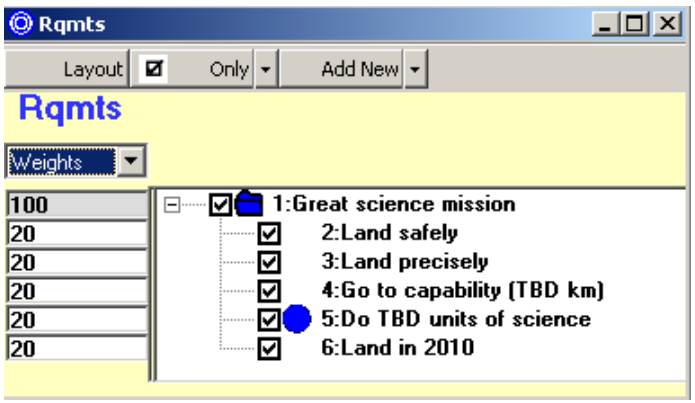
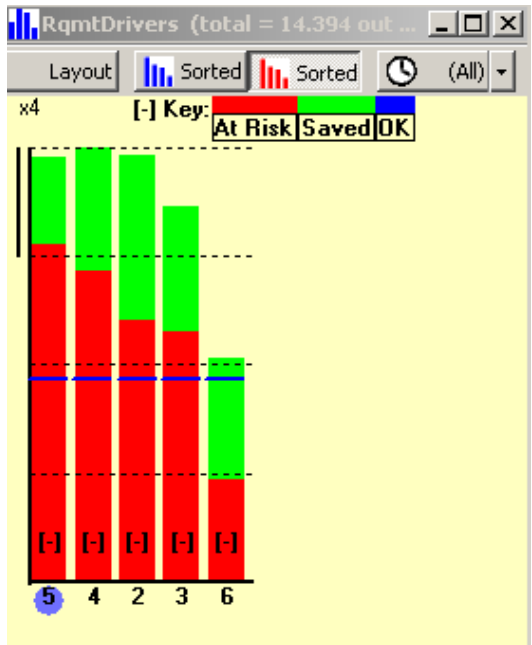
MSL Level 1 Requirements

at risk/mitigated by Technology Program investment





Total Height= Extent to which requirement is at risk due to Technology Risks
Green is extent to which risk is reduced with application of Technology Plan
Red is extent to which requirement is still at risk

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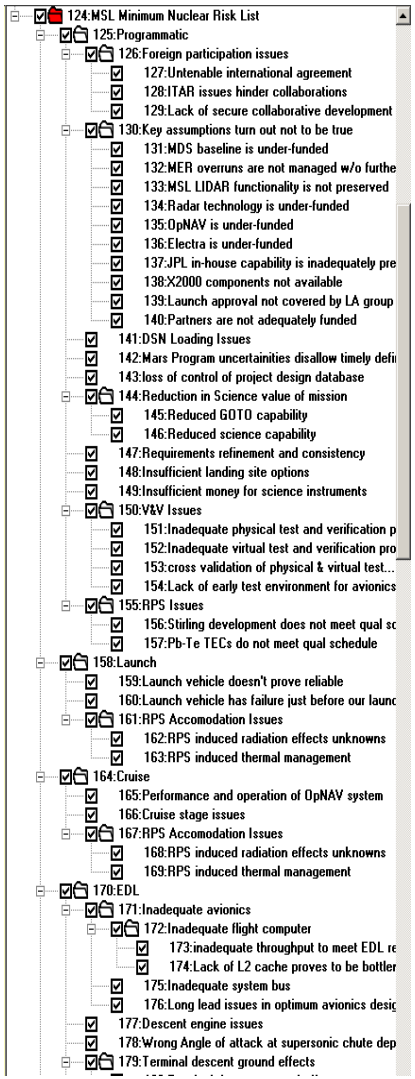
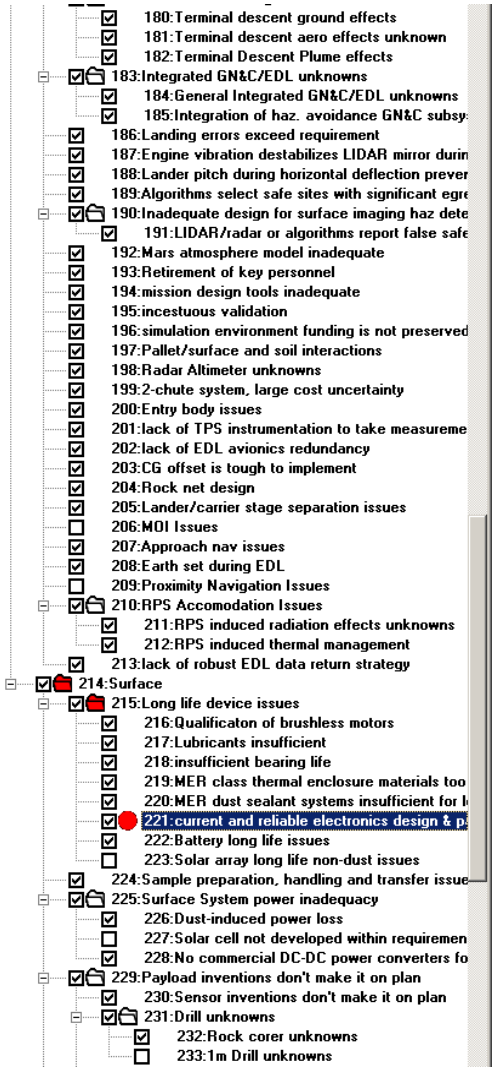
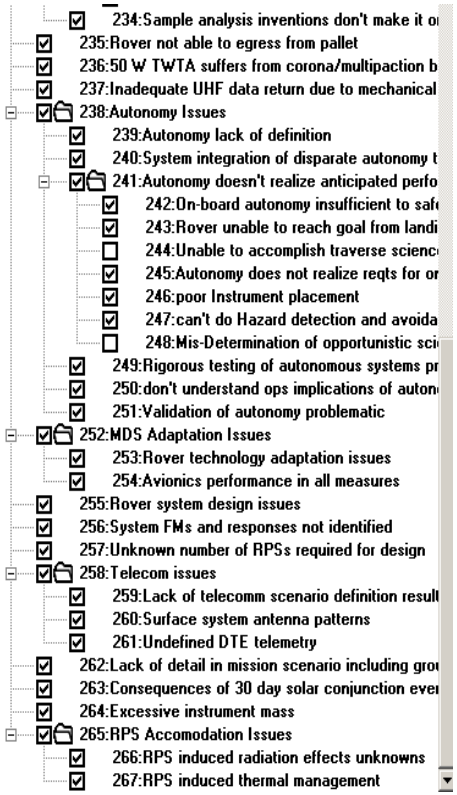
Risk Identified







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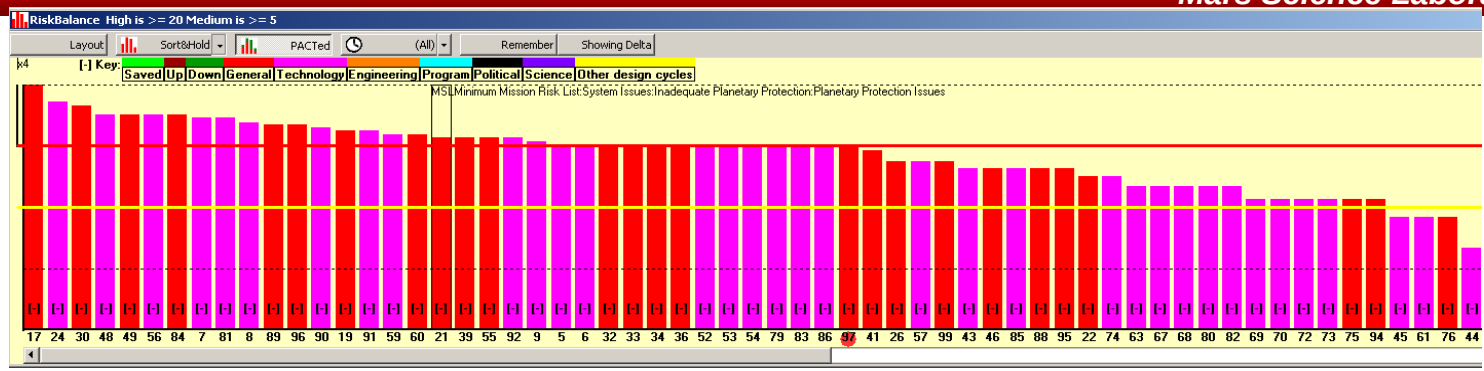
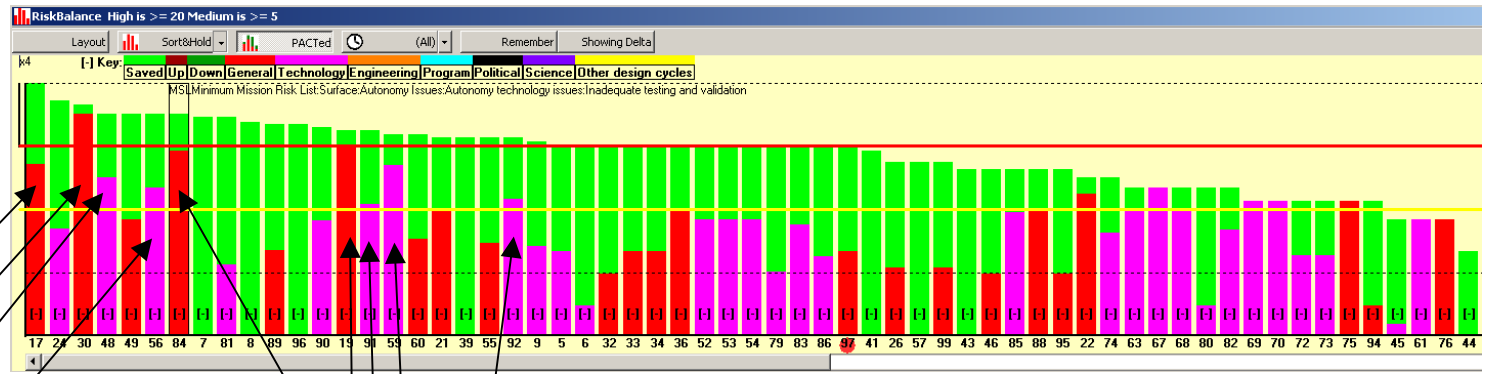
Risk List (Minimum Mission)
before/after application of Technology Program investments

Mars Science Laboratory





System FMs and responses not identified

Lack of L2 cache proves to be bottleneck

Inadequate detailed simulation for EDL new tech

Current and reliable electronics design & packaging technologies insufficient in Mars thermal environment

Inadequate autonomy testing and validation

System mass of engineering elements of rover exceed allowable limits

Dust-induced power loss

Inadequate autonomic Hazard detection and avoidance

Validation of autonomy problematic

Legend
Purple= Technology Risks
Red=Technology/Engineering Risks
Green=Mitigated Risks
Red line= High/Medium risk boundary
Yellow line= Medium/Low risk boundary

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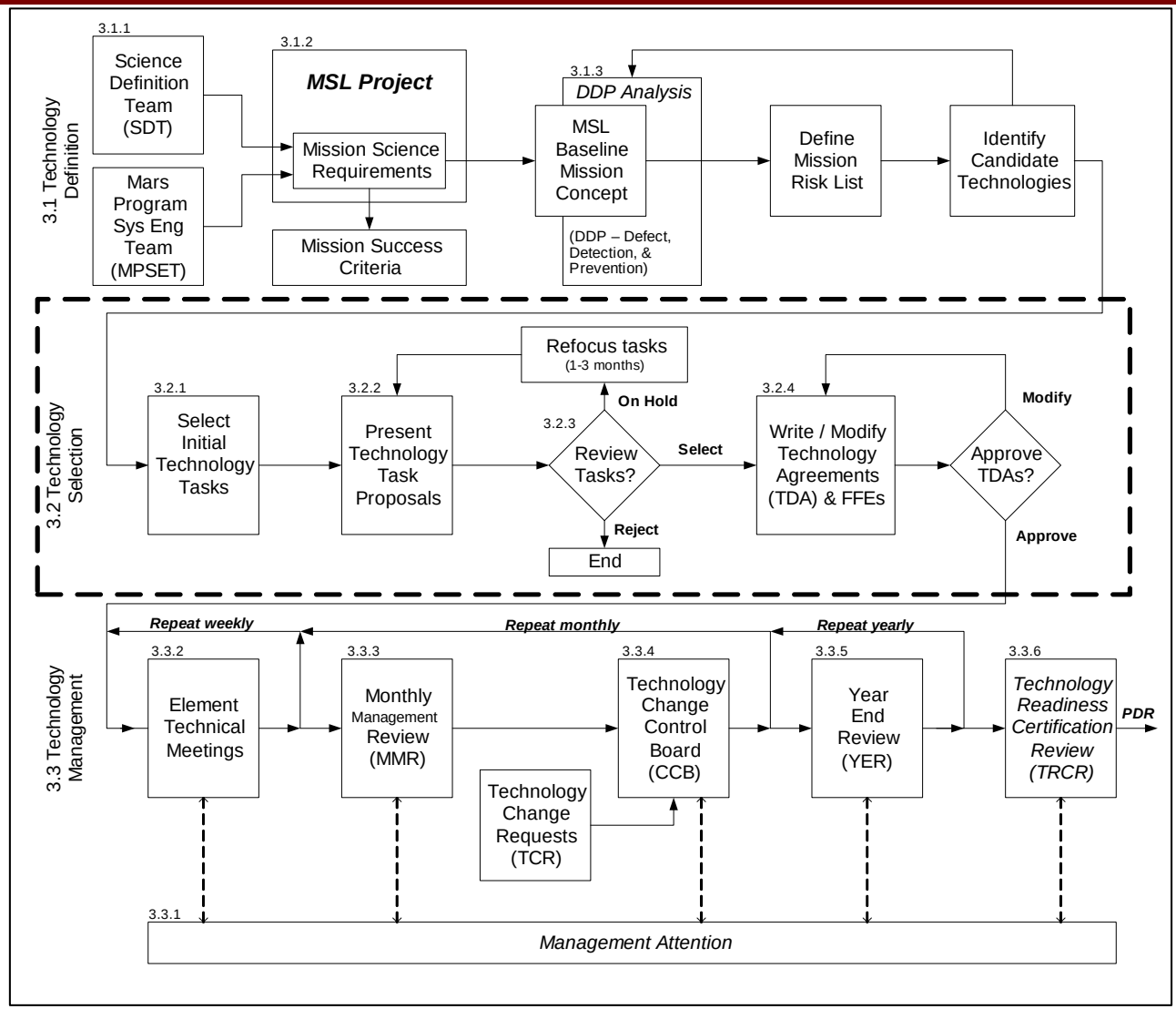
Technology Selection Process



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Prepare/Present Task Proposals

(based on mission concept, performance requirements, risk list)

- *Overview (Quad Chart)* – One slide summary of the task including a picture, objectives, milestones, organizations, subtasks, schedule, and funding levels
- *Objectives and approach* – Describes objectives, state of the art, performance goals, and implementation approach
- *Backup data* – Data for reviews to assess the impact, sensitivity, risks, and procurements of the task
- *Receivable/Deliverable Lists* – List all items being received by the task and delivered from the task to a project element.
- Budget Estimates – Assessment of costs to complete task

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Prepare, Review, and Approve TDA

- *Introduction* – Describes the technology, assesses the state-of-the-art, and defines the current TRL.
- *Objectives* – Describes the task's technical objectives and goals.
- *Technical Approach* – Describes the methodology and approaches to conduct the proposed development.
- *Significance* – Explains how the task will contribute to a NASA Mission.
- *Milestones and Deliverables* – Identifies when major milestones will be achieved.
- *Funding Distribution* – Lists the budget, who is funded, which year, and totals
- *Documented Partnerships/Cooperative Agreements* – Describes any partnerships, cooperative agreements, or other agreements that involve this task.
- *Comments* – The following questions determine the tasks funding sensitivity, work breakdown, task dependencies, and other issues associated with the task:
- *Infusion Plan* – Defines the plan for applying the technology developed in this task to a practical implementation.
- *Reporting Plan* – Defines the plan for reporting status/progress on this task to project.
- *Commercialization Plan* – Defines the plan for transferring the technology developed in this task to commercial use.
- *Approval* – The TDA sequence of approval is: Task Manager, Element Manager (or Level-1 Manager), Section Manager, and Project Office.

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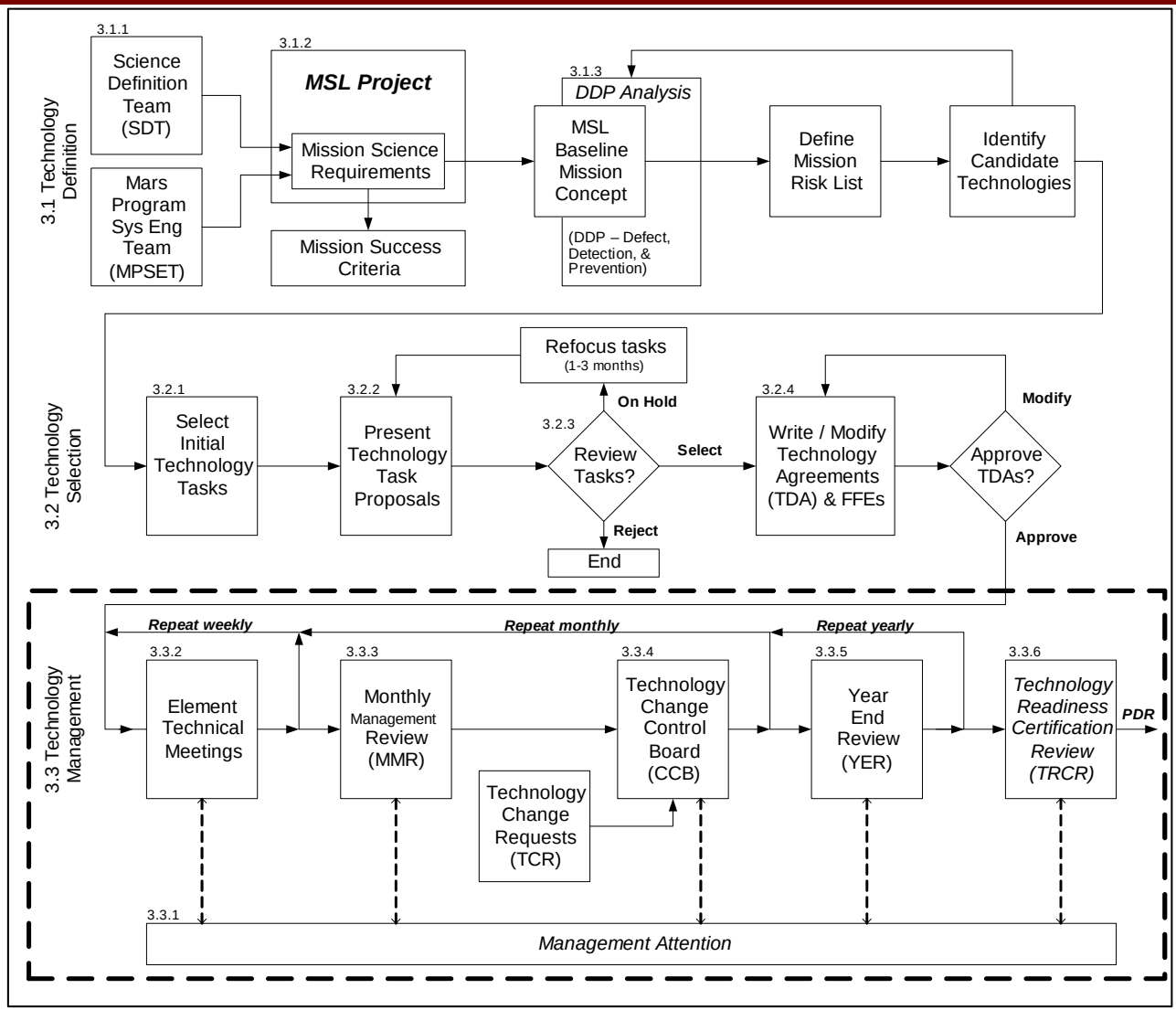
Technology Management Process



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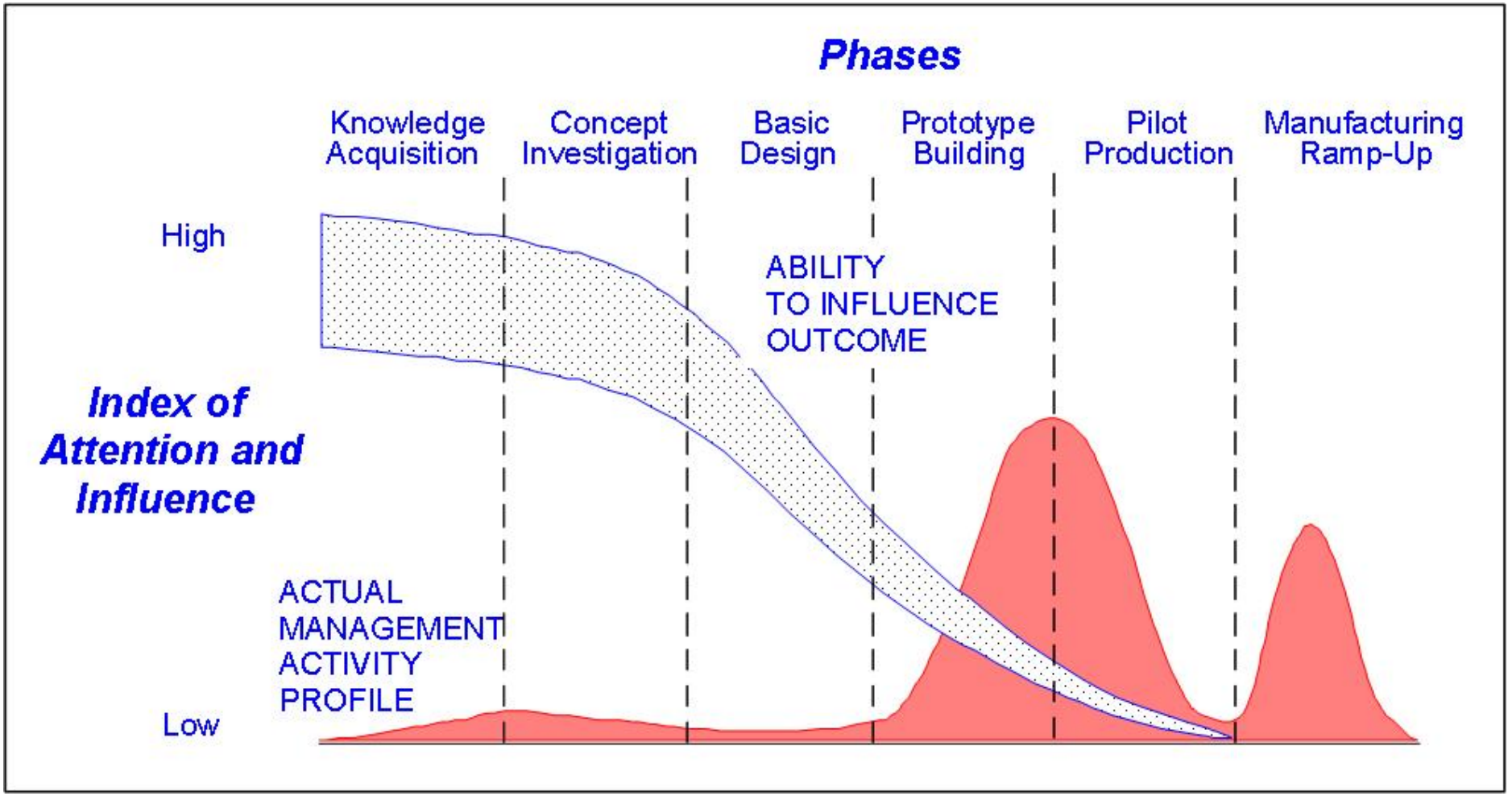
Timing and Impact of Management Attention and Influence



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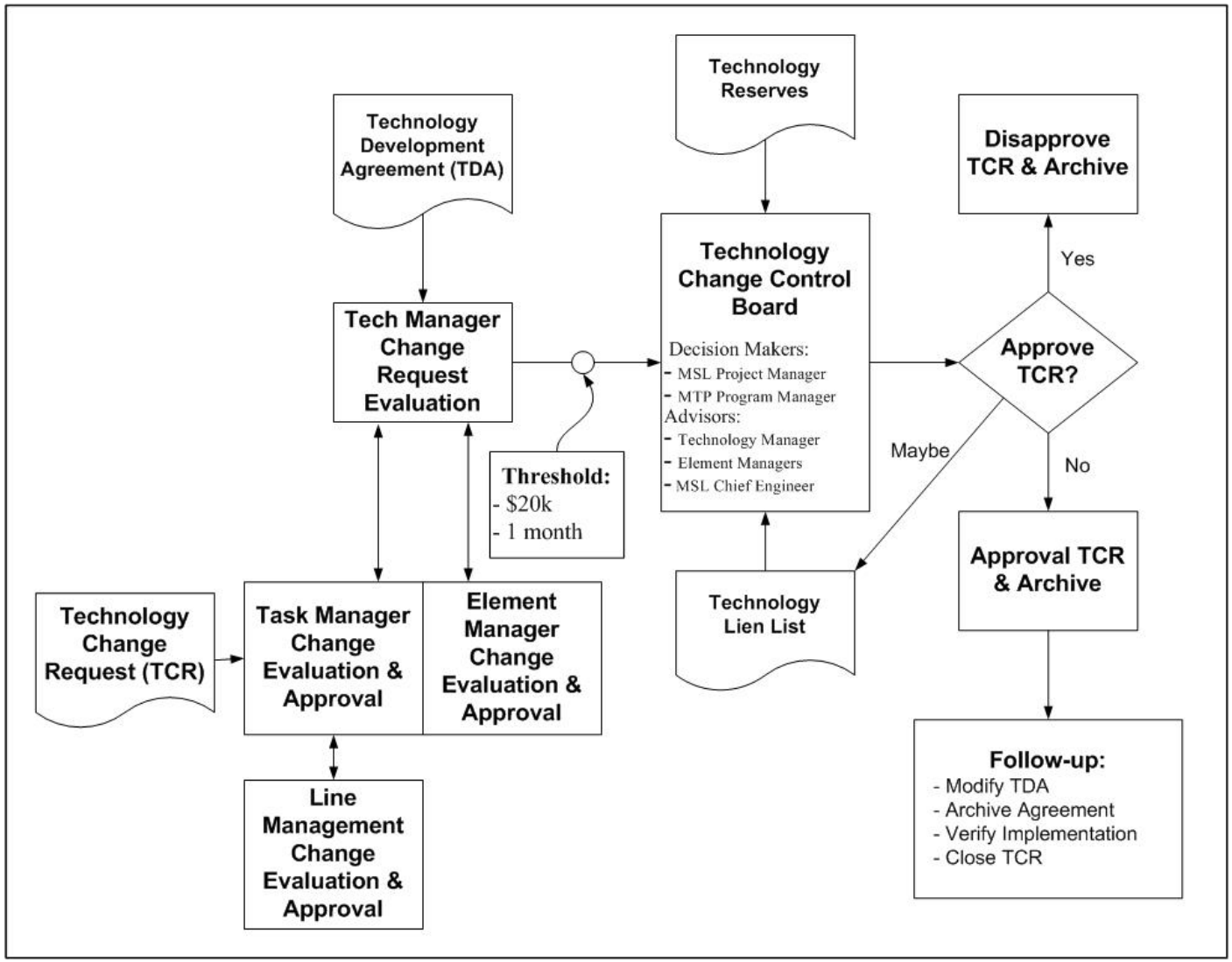
MSL Technology Change Control Flow



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Technology Readiness Certification Review

Goals:

- **Establish MSL technology infusion maturity requirements**
- **Establish criteria based on TRL guidelines**
- **Specific criteria to be assigned to individual MSL FT tasks**

Maturity criteria—Hardware

- **Design**
  - Drawings
  - Materials/parts selection
  - Analyses - Thermal, loads and accoustics
  - CG, Mass, Volume, and Power estimates
  - Performance (improvement) estimate
- **Fabrication and Assembly**
  - Fab instructions
  - Flight-like materials used
  - Inspection
  - Unit assembled in flight-like configuration
  - Mass, CG properties
- **Test (after application of power)**
  - Performance/functional testing
  - Environmental testing
  - Power measured
  - Idiosyncracies documented

Maturity criteria—Software

- **Design**
  - Performance estimate
  - State analysis products (or FDDs)
  - CPU, memory utilization
  - Source code/algorithm descriptions
  - Test Cases
- **Fabrication**
  - Flight-like development environment
  - Flight approved compiler and libraries
  - Flight computer/OS compatible
- **Test**
  - Executed on flight-like hardware and OS
  - Performance/functionality demonstrated
  - Measured CPU, memory utilization
  - Idiosyncrasies documented

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Technology Management Tools

- Aggregate Project Plan (Bubble Chart)
- The MSL Technology Funnel Chart
- Technology Decision Analysis Tools
- Deliverable / Risk Analysis Tools

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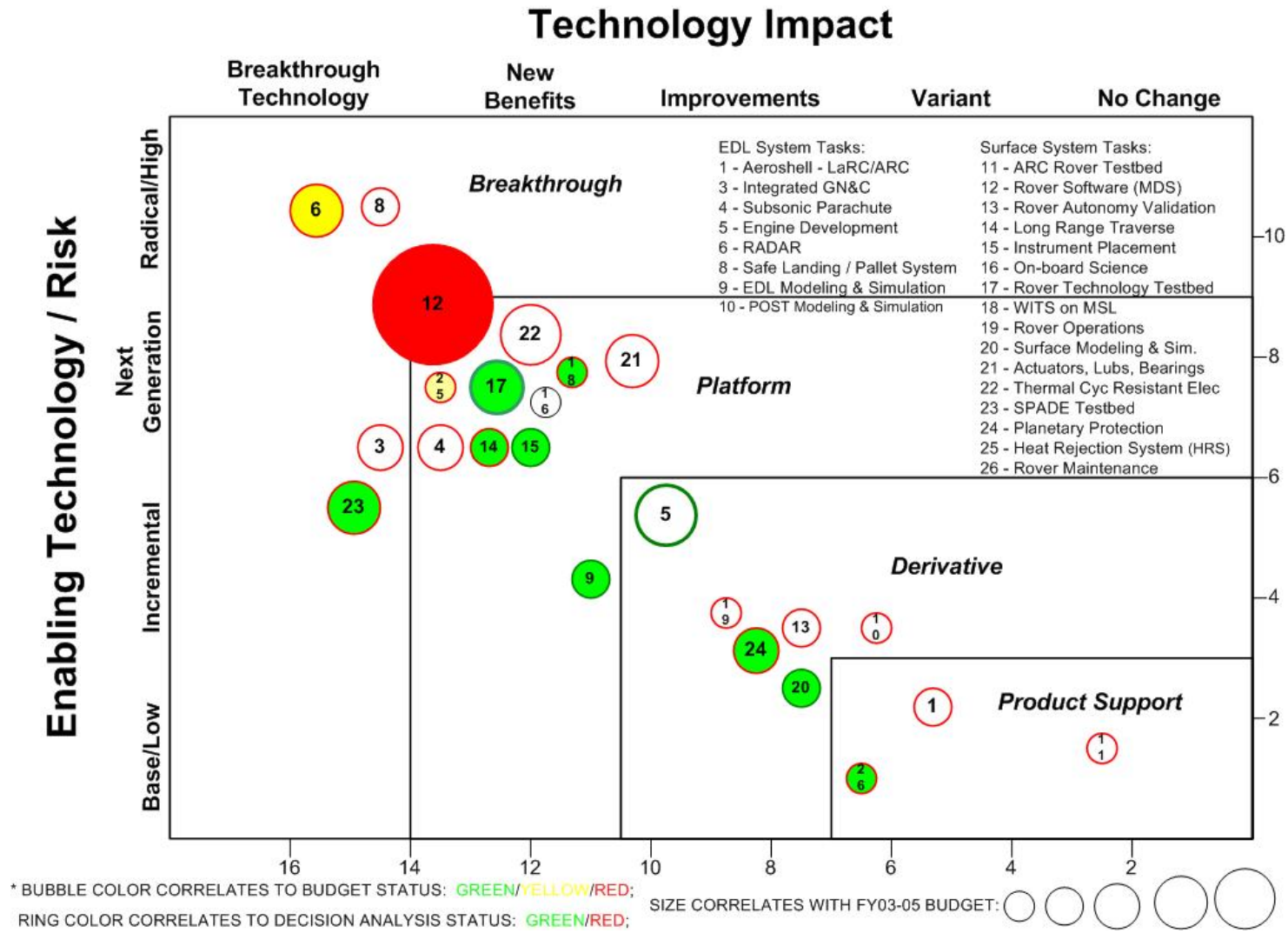
Aggregate Project Plan (Bubble Chart)



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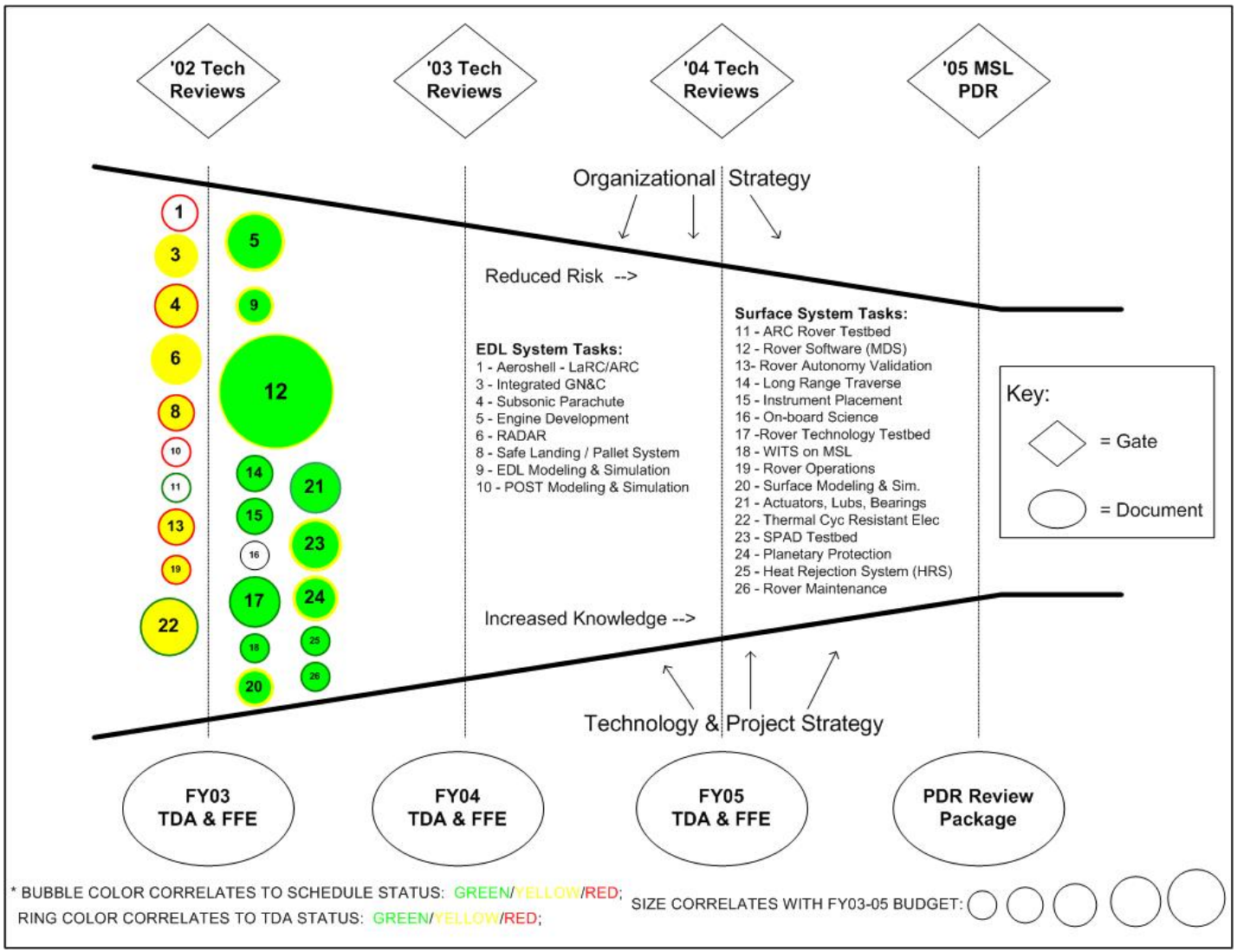
The MSL Technology Funnel Chart



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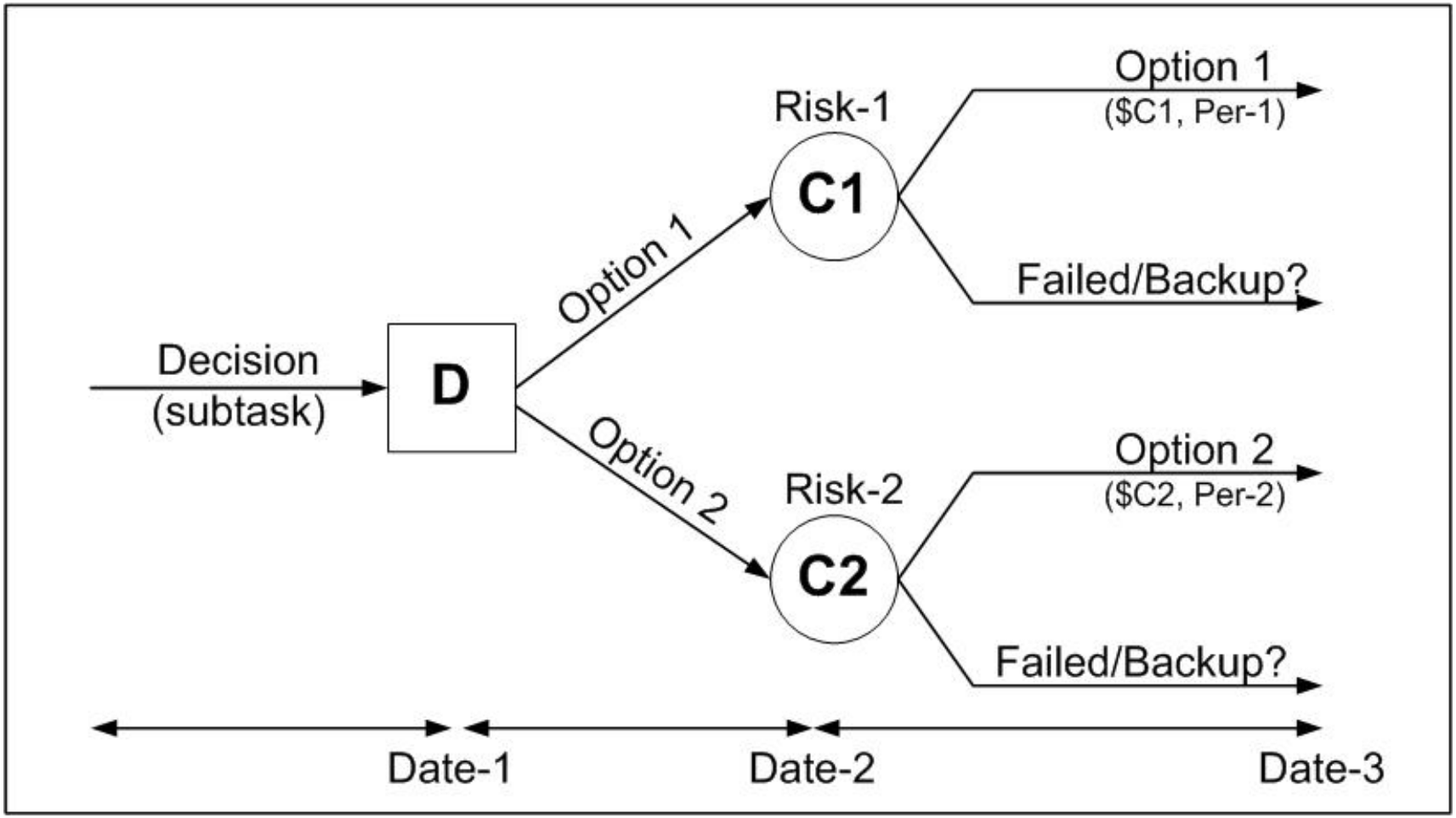
Technology Decision Analysis Tools



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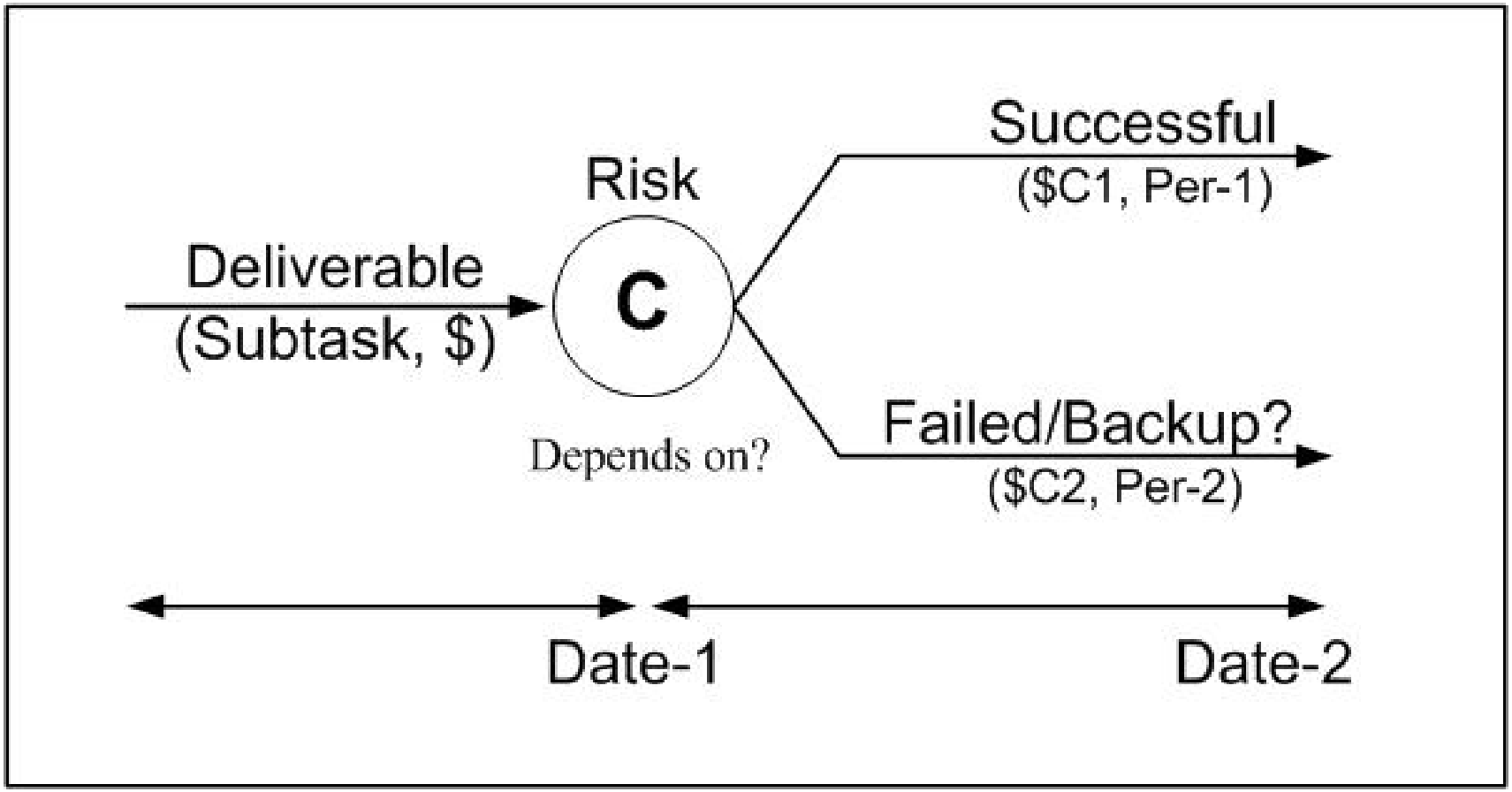
Deliverable / Risk Analysis Tools



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MSL Focused Technology Summary

- **The MSL Technology Program is tightly coupled to the MSL mission and the its milestones**
- **It involves critical deliverables that must be developed in time for infusion into the MSL mission**
- **The plan is to reach TRL 6 for each technology by the mission's PDR**
- **This program transcends the usual gulf between technology and projects by vertically integrating the technology work with pre-project development in a project-like environment with critical dates for technology infusion**
- **The program addresses developing key technology to enable MSL's revolutionary science mission**

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Acknowledgements

- Michael Sander (MSL Project Manager)
- Charles Whetsel and Charles Weisbin (MEP)
- Curt Henry (MSL System Engineer)
- Brian Muirhead (MSL Chief Engineer)
- Alice West (MSL Resources)
- Dave Woerner, Richard Volpe, Jeffery Umland, Jeffrey Simmons, and Sandy Krasner (Elm Mngs)
- Nancy Schweiner and Irene Lopez (project sup)
- All the MSL Task Managers

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